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No. 856.

FRICTION COEFFICIENT FOR RIVETED STEEL PIPE.

An Informal Discussion at the Annual Convention, June 28th, 1899.

SUBJECT FOR DISCUSSION.

"What is the Proper Friction Coefficient for use in the design of Riveted Steel Pipe?"

By A. McL. HAWKS, Jun. Am. Soc. C. E.

Mr. Hawkes.

A. McL. HAWKS, Jun. Am. Soc. C. E. (by letter).—The writer has tested the flow in a 14-in riveted steel pipe after it had been in service over three years, and again nearly three years later. As these measurements were carefully checked by volumetric determinations after weir flows were measured; as they check very closely with one another, and as they were made upon the main inflow of a system in the ordinary everyday uses to which such a main is applied, they will be a guide to designing similar pipes for such purposes.

This main is made of soft steel, is 14 ins. clear diameter of the smaller ring, and has double-riveted longitudinal seams and single-riveted circumferential seams. The double riveting is spaced $\frac{4}{4}\frac{5}{6}$ in. between rows, $\frac{5}{8}\frac{4}{4}$ in. to $1\frac{3}{8}\frac{2}{4}$ ins. between heads, and staggered. The circumferential rivets are $\frac{4}{6}\frac{5}{4}$ in. from center to center upon the exterior surface, or about $\frac{1}{2}$ in. from center to center on the interior surface, varying slightly with the thickness of the steel, the gauge of which

Mr. Hawks. runs from No. 9 to No. 12. All rivet heads are circular or "snap heads," and as the diameter of the rivets is $\frac{15}{64}$ to $\frac{21}{64}$ in., the heads form almost a complete ring upon the interior of the pipe, and practically reduce the clear opening about $\frac{1}{4}$ in. An attempt was made to compensate for this by making the interior rings a slight fraction of an inch greater than the size originally planned. As the outer rings were kept uniform, this increased size amounts to about $\frac{1}{8}$ in. in the lighter and $\frac{1}{16}$ in. in the heavier steel.

Seven rings of steel plate (four of the greater and three of the lesser diameter) formed a 24-ft. length of pipe as made up in the shop. One end was reinforced with a 5-in. welded steel ring of 14 ins. clear diameter, the end lengths of the pipe being of the greater diameter and the end longitudinal rivets being practically countersunk to admit this reinforcer. In making up the pipe lengths the longitudinal seams were "in line" in alternate rings and "quartering" in adjacent rings.

All lengths were thoroughly cleaned and dipped in a hot asphaltum bath, being left a sufficient length of time for the metal to attain the temperature of the bath. All lengths were inspected and tested previous to leaving the shop. That this work was thoroughly well done is shown by the fact that some extra lengths and extra rings were left exposed to the weather along the line of the work, and the coating of these was in fairly good condition after more than six years.

In laying the pipe in the trench the longitudinal seams were placed so as to form an angle of 45° with the vertical plane; the reinforcer, which projected half its width from the end of the pipe, was forced into the next length until the exterior rings were in contact. An exterior welded ring $\frac{3}{8}$ in. thick and 5 ins. wide was drawn over the joint and an ordinary lead joint was poured and caulked.

As will be seen from the above, the obstructions to flow are: 1st, the circle of rivet heads of the transverse joints, about $3\frac{1}{2}$ ft. apart; 2d, the lap of the rings; 3d, the reinforcing rings, 24 ft. apart; and 4th, the double line of rivet heads making the longitudinal seams.

The total length of this pipe line is 70 700 ft., leading from an iron screen chamber, near the inlet, to the distributing reservoir. The profile of the pipe line is fairly smooth, there being four principal summits (two approaching the hydraulic grade line) and five principal depressions (two approaching zero of the datum plane); the remainder is chiefly along benches with easy grades. Automatic air-valves are provided for all summits and blow-off gates for all depressions. The alignment is very easy, no quick bends occurring in the whole length. In two places where 90° curves are required they are made with six 15° cast-iron pipes. Therefore, no allowance for friction in bends is necessary in the calculations.

This work was completed in the fall of 1892. In April, 1896, the writer tested it, and the following are his notes:

April 2d.—Visited intake and headworks. At 1.30 P. M. measured depth of water in screen chamber, which was 7.98 ft., making elevation of surface of water 429.15 above datum. Mr. Hawks.

April 3d. Weir test.—The weir was a square notch, 15 ins. wide, cut in a sheet of No. 8 steel, set in the overflow chamber of the reservoir. All the conditions surrounding it were favorable to using the Francis formula, with end contractions: Discharge $3.366 \times$ (length of overfall$-\frac{1}{5}\,h$) $\times \sqrt{h^3}$, and this was used in calculating the discharge.

As the total outflow was only 1 cu. ft. per second and the area of the approach channel was 2.8 ft. $\times$ 3.1 ft., or nearly 9 sq. ft., the velocity of approach was disregarded.

Reading on gauge at	8	P. M.	.....	4	ins.
" "	" 10	"	.....	$4\frac{5}{8}$	"
" "	" 10.15	"	.....	$4\frac{5}{8}$ +	"

The weir was then closed for 15 minutes to allow the reservoir to fill to a higher level. It was reopened at 10.30 P. M., when the reading on the gauge was $4\frac{7}{8}$ ins. It gradually fell until at the close of the test it read $4\frac{5}{8}$ + ins., and remained stationary at that figure for 30 minutes.

Elevation of surface water = 396.95 ft. above datum.

April 4th. Volumetric Test.—The supply to the city was cut off at 7.20 P. M.

Gauge reading at	7.30	P. M.	.....	11 ft.	$5\frac{5}{8}$ ins.		
" "	7.45	"	.....	11 "	6 "	$\frac{3}{8}$	-in. rise.
" "	8	"	.....	11 "	$6\frac{3}{8}$ "	$\frac{3}{8}$	"
" "	8.15	"	.....	11 "	$6\frac{7}{8}$ "	$\frac{4}{8}$	"
" "	8.30	"	.....	11 "	$7\frac{1}{4}$ "	$\frac{3}{8}$	"
" "	8.45	"	.....	11 "	$7\frac{3}{4}$ "	$\frac{4}{8}$	"
" "	9	"	.....	11 "	$8\frac{1}{8}$ "	$\frac{3}{8}$	"
" "	9.15	"	.....	11 "	$8\frac{5}{8}$ "	$\frac{4}{8}$	"
" "	9.30	"	.....	11 "	$9\frac{1}{8}$ "	$\frac{4}{8}$	"
" "	9.45	"	.....	11 "	$9\frac{1}{2}$ "	$\frac{3}{8}$	"
" "	10	"	.....	11 "	$9\frac{7}{8}$ "	$\frac{3}{8}$	"

The first and last readings were taken most carefully. Intermediates were taken to roughly check the results.

The total rise was 0.35 ft. in $2\frac{1}{2}$ hours.

After this test was completed the water was cut off from the reservoir, and it was left to stand full until morning. As the gauge read precisely the same at the end of 12 hours it was evident that no leakage of moment had occurred during this test.

The flow over the weir was calculated to be 0.96 cu. ft. per second.

Discharge $= 3.366 \times (l - \frac{1}{5}\,h) \times \sqrt{h^3} = 3.366 \times (1.25 - 0.08) \times \sqrt{(3.9)^3} = 3.938 \times 0.244 = 0.96$ cu. ft. per second.

Mr. Hawks. The rate of inflow was 0.99 cu. ft. per second. The average area of the reservoir surface at time of filling = 25 225 sq. ft.

Rise of 0.35 ft. over an area of 25 225 sq. ft.	= 8 829 cu. ft.
Allowance for voids in paving.....	65 "
Total.....	8 894 cu. ft.

Total inflow = 8 894 cu. ft. in $2\frac{1}{2}$ hours (9 000 seconds), or at the rate of 0.99 cu. ft. per second.

This rate of discharge agrees nearly with the calculated discharge by Kutter's formula if the coefficient of friction $n = 0.013$ be used.

$$S = \frac{429.15 - 396.95}{70\,700} = \frac{32.2}{70\,700} = 0.000455.$$

$$V = C\sqrt{R\,S} = 87\sqrt{0.292 \times 0.000455} = 87 \times 0.0115 = 1.0005 \text{ ft. per second.}$$

Discharge = $1.069 \times 1.0005 = 1.07$ cu. ft. per second.

In February, 1899, the writer was called upon to measure again the flow through the same main, under a slightly greater head. A weir box 22 ins. wide, 20 ins. deep and 9 ft. 3 ins. long, was built at the inflow of the reservoir, having a 90° triangular notch of No. 20 sheet iron at the outflow end. Through this the water flowed 8.9 ins. deep. Using Thomson's formula for the discharge of triangular notches: The discharge $= 0.0051 \times \sqrt{h^5} = 0.0051 \times 237 = 1.209$ cu. ft. per second.

A volumetric test was made by allowing the water to flow freely into the reservoir for 4 hours 5 minutes. The average area of the water surface was 13 149 sq. ft., upon which the rise was 1.34 ft.

Rise of 1.34 ft. over an area of 13 149 sq. ft.	= 17 620 cu. ft.
Allowance for voids in paving.....	80 "
Total.....	17 700 cu. ft.

Total inflow 17 700 cu. ft. in 4 hours 5 minutes (14 700 seconds), or at the rate of 1.204 cu. ft. per second.

Notes of Volumetric Test.—The supply to city was cut off at 8.30 P.M.

Gauge reading at	8.45 P. M.	2 ft.	$1\frac{1}{10}$ ins.			
"	" 9	"	2 "	$2\frac{1}{4}$ "	1.15 ins.	rise.
"	" 9.30	"	2 "	$4\frac{1}{4}$ "	2	"
"	" 10	"	2 "	$6\frac{1}{4}$ "	2	"
"	" 10.30	"	2 "	$8\frac{1}{8}$ "	$1\frac{7}{8}$	"
"	" 11	"	2 "	$10\frac{1}{8}$ "	2	"
"	" 11.30	"	3 "	$0\frac{1}{8}$ "	2	"
"	" 12	M.	3 "	2 "	$1\frac{7}{8}$	"
"	" 12.50	A. M.	3 "	$5\frac{2}{10}$ "	3.2	"

At which time the reservoir was cut off for 12 hours. No leakage was observed.

The first and last readings were taken most carefully. Intermediates were taken as rough checks. Mr. Hawks.

This rate of discharge nearly agrees with the calculated discharge by Kutter's formula if the coefficient of friction $n = 0.013$ be used.

$$S = \frac{430.3 - 389.0}{70\,700} = \frac{41.3}{70\,700} = 0.000584.$$

$$V = C\sqrt{R\,S} = 87\sqrt{292 \times 0.000584} = 87 \times 0.0132 = 1.148 \text{ ft. per second.}$$

Discharge $= 1.069 \times 1.148 = 1.227$ cu. ft. per second.

From these two tests the writer is led to believe that, for similar pipes under like heads, the coefficient of friction, $n = 0.013$, is approximately correct.

He also wishes to draw attention to the fact that there has been practically no decrease in the discharge of the main after it has been in use more than six years. From all the data he can gather, he is of the opinion that, for the first ten years of its life, such a main can be depended upon to give its full calculated discharge.